9.2.1.2 Status of the Species at Proposed Action Area Preconstruction and Construction Sites

The following sections provide additional detail about habitat conditions in specific areas where CWF proposes construction activities. The status of the delta smelt at these proposed construction areas is dependent on the species' range-wide status because the CWF construction is all proposed to occur in seasonally or transiently used habitats that will be occupied and used by fish in general proportion to their overall range-wide abundance.

Sacramento River from I Street Bridge in Sacramento to its Confluence with Cache Slough at Grand Island and the Primary Distributary Channels Steamboat Slough, Georgiana Slough, and the Delta Cross Channel

The adjacent land use along most of this river reach has been urban (Sacramento) or agricultural since the 1860s-1890s (Whipple *et al.* 2012; Figure 9.2.1.2-1). Major changes include deforestation of the natural levees, disconnection of the river from its flanking floodplains, extensive levee reinforcement with riprap, and an initial increase in sediment, followed by a long-term decrease that has changed the tidal prism of this river reach. Reclamation constructed the Delta Cross Channel (DCC) in 1944 from the Sacramento River at Walnut Grove to the North Fork Mokelumne River to increase the flow of Sacramento River water across the Delta. When the DCC gates are opened, Sacramento River water flows into the North Fork of the Mokelumne River, which then flows into the San Joaquin River between Bouldin and Andrus islands.

Historically, the Sacramento River and its distributary sloughs had a well-developed riparian corridor along large natural levees that separated this river segment from its flanking floodplains (Whipple *et al.* 2012). The fringing riparian forest varied from several hundred feet wide to about one mile wide depending on location. The river did not meander here. Rather, floodwaters flowed into the Yolo basin at Knights Landing Ridge and into the Sacramento basin at the confluence of the American River. The Sacramento basin connection has been severed to develop and protect the greater Sacramento urban area. The Yolo basin connection has been muted by Fremont and Sacramento weirs, and levees that separate the Yolo Bypass from adjacent land areas, but the connection is not completely severed. The Yolo Bypass continues to route flood flows away from the Sacramento urban area (Sommer *et al.* 2001).

Presently, urban and agricultural land uses encroach to the landside of the existing reinforced levee system and little riparian habitat remains (Figures 9.2.1.2-2 and 9.2.1.2-3). This reach of the Sacramento River also includes a 286 cfs capacity water diversion operated by the Freeport Regional Water Authority, and the outfall for the Sacramento Regional Wastewater Treatment Plant. The positive barrier fish screens on the Freeport diversion preclude post larval fishes from being entrained. Larval fish sampling behind the Freeport fish screens was conducted from 2012-2014; no delta smelt larvae were found, though a small number of wakasagi larvae were collected (CWF BA 2016). The only significant natural habitat area adjacent to this river reach is the Stone Lakes National Wildlife Refuge near the City of Elk Grove. However, the refuge has no natural connection to the river and therefore provides no habitat value to delta smelt.

Hydraulic mining made this reach of the Sacramento River much shallower (and non-tidal) during the late 19th and early 20th centuries, but the sediment has dispersed over time and the river has regained its tidal influence (Whipple *et al.* 2012). Although under tidal influence, this reach of the Sacramento River is a major CVP and SWP water conveyance channel. Thus, flows are almost always high enough such that net flow is downstream even during flood tides (CWF BA 2016). The sediment supply carried into the estuary via the Sacramento River declined by 50% from the latter 1950s to the early 2000s (Wright and Schoellhamer 2004). Most of the sediment currently delivered to the estuary from this and other sources occurs during periods of high flow because sediment delivery rates steepen as inflows increase (Wright and Schoellhamer 2005).

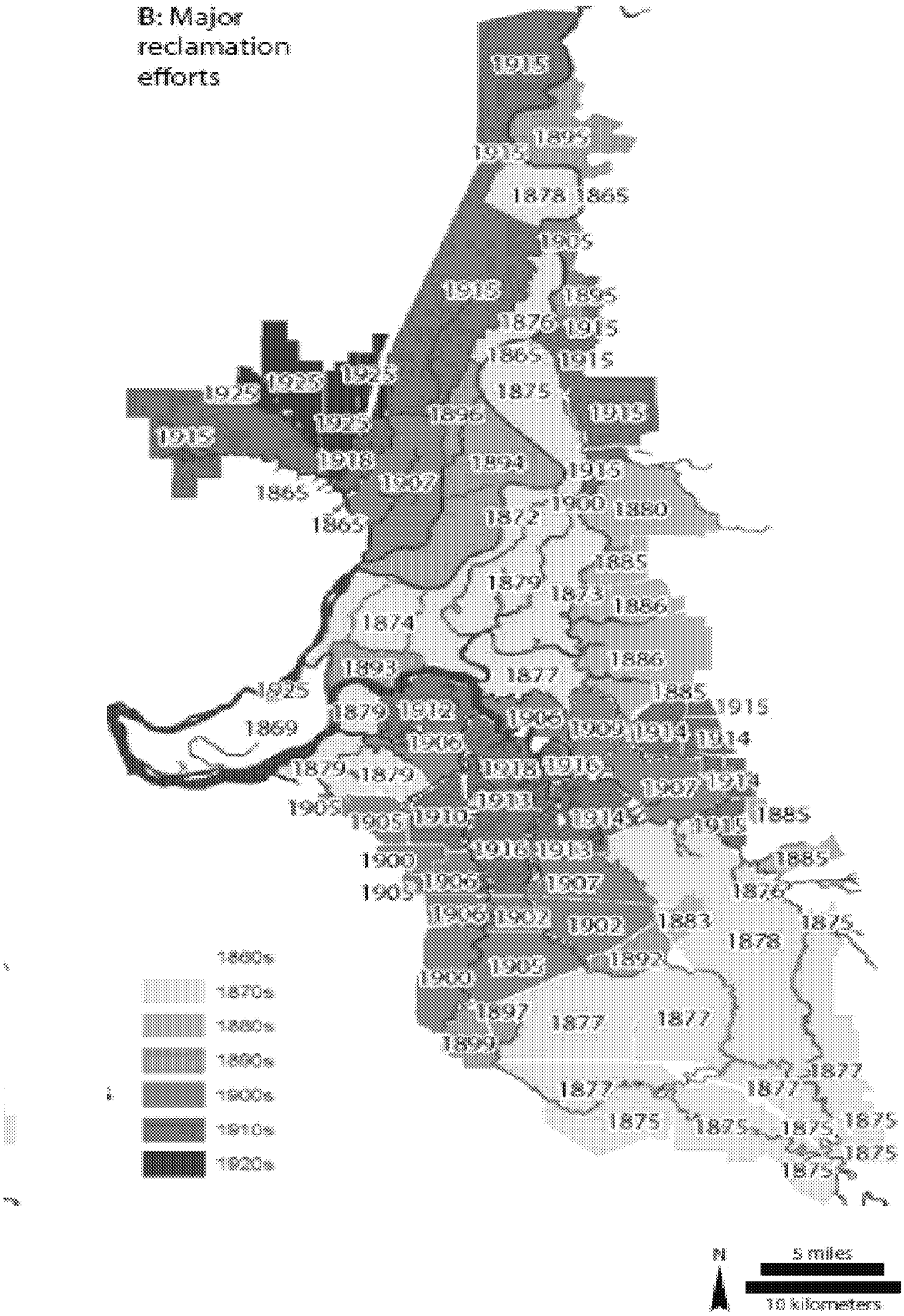

Figure 9.2.1.2-1. Map of the Delta showing dates of island conversion to agriculture. Taken from Whipple *et al.* (2012).

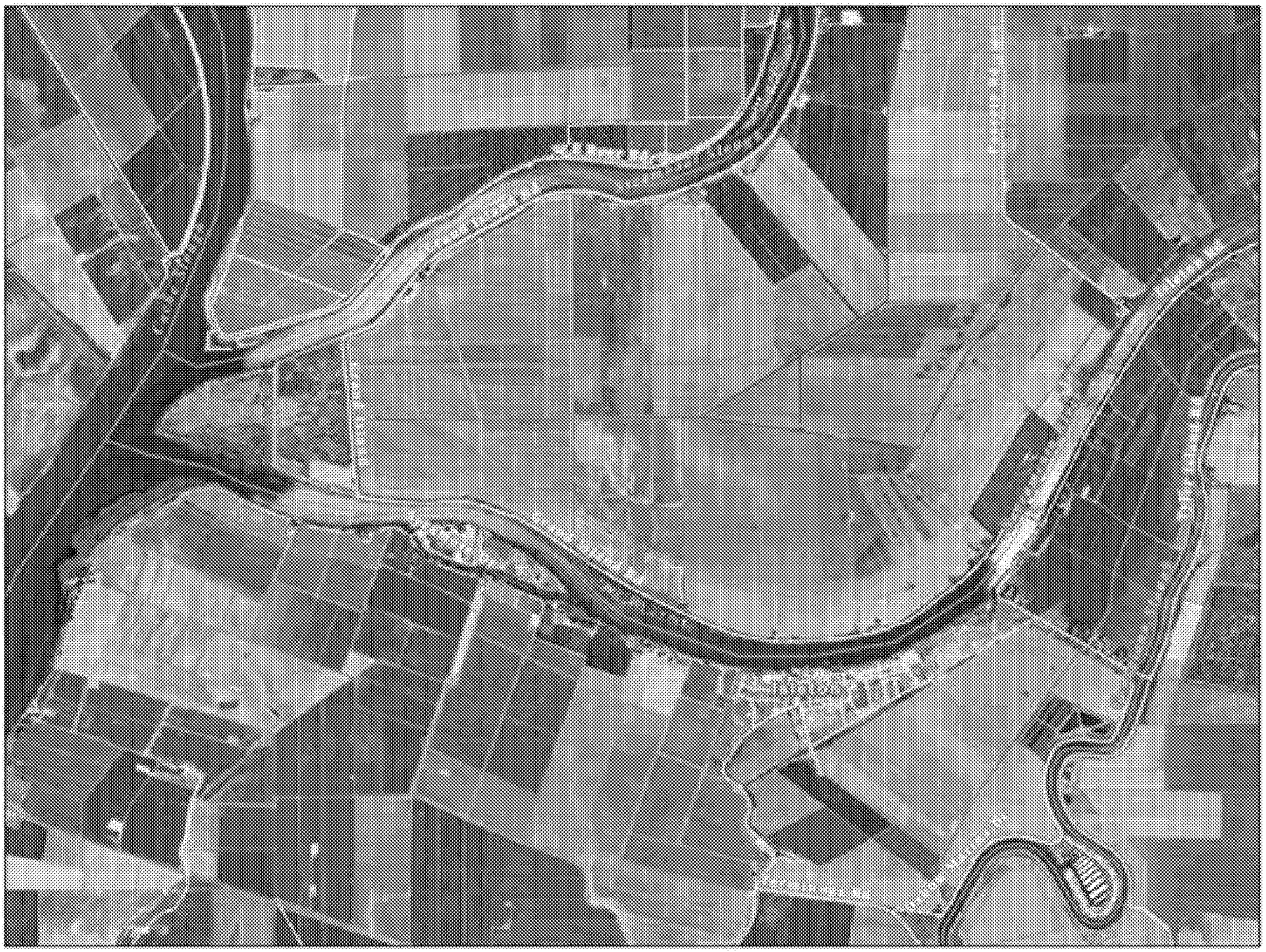

Figure 9.2.1.2-2. National Agriculture Imagery Program (2016) aerial image of the Sacramento River in the vicinity of Isleton.

Figure 9.2.1.2-3. National Agriculture Imagery Program (2016) aerial image of the Sacramento River in the vicinity of Garcia Bend.

Food web: The Sacramento River from Sacramento to Isleton and its primary distributaries are low productivity channels and have been for several decades (Orsi and Mecum 1986). This may be due to the canal shape of these channels and the rapid conveyance of river water into the Delta. However, there are also water chemistry-related reasons for this area's low productivity. For instance, chlorophyll concentrations in the Sacramento River decline rapidly as it flows past the City of Sacramento, suggesting a toxic effect on primary productivity (Parker *et al.* 2012). Parker *et al.* (2012) proposed ammonium inhibition of phytoplankton growth as the mechanism generating this pattern. In addition, toxicity to invertebrates related to urban pesticide runoff has been observed in the American River, which flows into the Sacramento River in the city limits (Weston *et al.* 2012). Thus, this river reach is not presently a major source of immediately available zooplankton production for delta smelt to prey on.

Adult migration and spawning: The results of DSM-2 PTM modeling show that there is no measurable probability tide-surfing particles intended to represent dispersing adult delta smelt could ascend the Sacramento River to the proposed NDD sites using only open off-channel habitats (CWF BA 2016). This makes intuitive sense for two reasons. First, the tidal energy extending up into Cache Slough is much greater than the tidal energy extending into the comparatively narrow mainstem channel of the Sacramento River so most particles that can move upstream move into Cache Slough. Second, both flood and ebb tide flows are usually moving downstream in the Sacramento River where the proposed NDD would be built. Once the tides stop flowing in two directions, the standard tide-surfing mechanisms, vertical and lateral changes in distribution during flood versus ebb tides, would no longer work to move fish upstream. However, adult delta smelt do ascend the Sacramento River (Merz *et al.* 2011), in one robustly documented instance, even reaching Knights Landing, which is well beyond the reach of tidal influence (Vincik and Julienne 2012). The most parsimonious explanation for how delta smelt can accomplish this against water velocities that exceed their sustained swimming speeds in mid-channel is to do something they do less frequently further downstream, which is to remain near the shoreline throughout the tidal cycle because near the shoreline, water velocities are slower.

If this hypothesis about migration tactics is correct, then we would expect to see low catches in trawls from this reach of the Sacramento River and relatively higher catches in nearshore beach seines. The available data support this hypothesis. The estimated densities of adult delta smelt in this river reach based on the CDFW SKT (station 724 at Ryde) are zero, although delta smelt have been collected in Service Kodiak trawling at Sherwood Harbor during January–March (detection in 5 years from 2002–2016). In contrast, detection frequencies based on the Service's Delta Juvenile Fishes Monitoring Program beach seine surveys are fairly high (Table 9.2.1.2-1).

Table 9.2.1.2-1. Summary of adult delta smelt detections (capture of at least one delta smelt in a beach seine) at sixteen sites along a transect of the Sacramento River and its primary distributaries from Decker Island to Verona. The sites SR012 and SR014 are downstream of the Sacramento River confluence with Cache Slough and reflect a permanently occupied baseline or background detection rate for this sampling program (86 to 90 percent; see far right column). The other sampling sites are seasonally or transiently occupied habitats that can be compared against SR012 and SR014. Green cells represent detections during January-June from 1994-2014, gray cells represent non-detections, yellow cells represent autumn detections, which were only reported a few times in relatively upstream locations and thus may represent misidentified wakasagi[20]. Data source: Delta Juvenile Fishes Monitoring Program, 1994-2014 (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm).

Location	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Frequency
SR012																						0.86
SR014																						0.90
SR017 (Isleton)																						0.38
SR024 (Koket)																						0.62
XC001 (DCC)																						0.05
GS010 (Georgiana Slough)																						0.19
SS011 (Steamboat Slough)																						0.43
SR043 (Clarksburg)																						0.71
SR049 (Garcia Bend)																						0.76
SR055 (Sherwood)																						0.00
SR057 (Miller Park)																						0.10
SR060 (Disco Park 1)																						0.19
AM001 (Disco Park 2)																						0.05
SR062 (Sand Cove)																						0.10
SR071 (Elkhorn)																						0.10
SR080 (Verona)																						0.10

[20] The raw catches and densities of fish collected using different gear types cannot be quantitatively compared unless studies have been conducted to calibrate the methods. The monitoring studies designed to target the delta smelt have been based on trawling techniques, but delta smelt have been incidentally collected using other gears from monitoring studies designed to target other species. For instance, the DJFMP beach seine survey was developed to monitor the distribution and relative density of Chinook salmon fry, but a few delta smelt are incidentally collected each year. There is no calibration information available to quantitatively compare the catches of delta smelt in trawl surveys to the catches in the DJFMP beach seine survey. Therefore, we have limited our analysis of the beach seine information to presence-absence in an effort to avoid misleading quantitative raw catch or density comparisons.

The beach seine data suggest that delta smelt use the Sacramento River between Isleton and Sacramento, and its primary distributaries, as a migratory corridor and spawning habitat. We conclude this because the vast majority of individuals collected are adult-sized fish during February-May (Figure 9.2.1.2-4). These recent observations of timing and location are consistent with a somewhat older study by Stevens (1963): "Evidently freshwater smelt leave the Courtland-Freeport area soon after their spawning period. Most specimens present in the stomachs of bass caught in this area had ripe ovaries or testes and only three were found after June 25."

Larval transport and juvenile rearing: Delta Smelt larvae that hatch in the Sacramento River above its confluence with Cache Slough typically encounter swift downstream currents that would rapidly transport them below the confluence with Cache Slough into larger channels with tidal flows that move upstream and downstream twice a day. Larvae can use this stronger tidal influence to help them maintain position in the estuary (Bennett *et al.* 2002). Larvae that hatch in Steamboat and Georgiana sloughs would likewise be rapidly moved downstream; however, larvae that hatch in Steamboat Slough would be transported to the same areas as larvae hatched in the Sacramento River whereas larvae hatching in Georgiana Slough would be transported to the San Joaquin River.

Juvenile delta smelt catches along the Sacramento River and its distributaries are rare above Cache Slough. During 1994-2014, only three were collected from Courtland and Garcia Bend, the two sampling sites nearest the proposed NDD locations (Figure 9.2.1.2-4). Thus, this part of the action area is for the most part, not a juvenile rearing habitat.

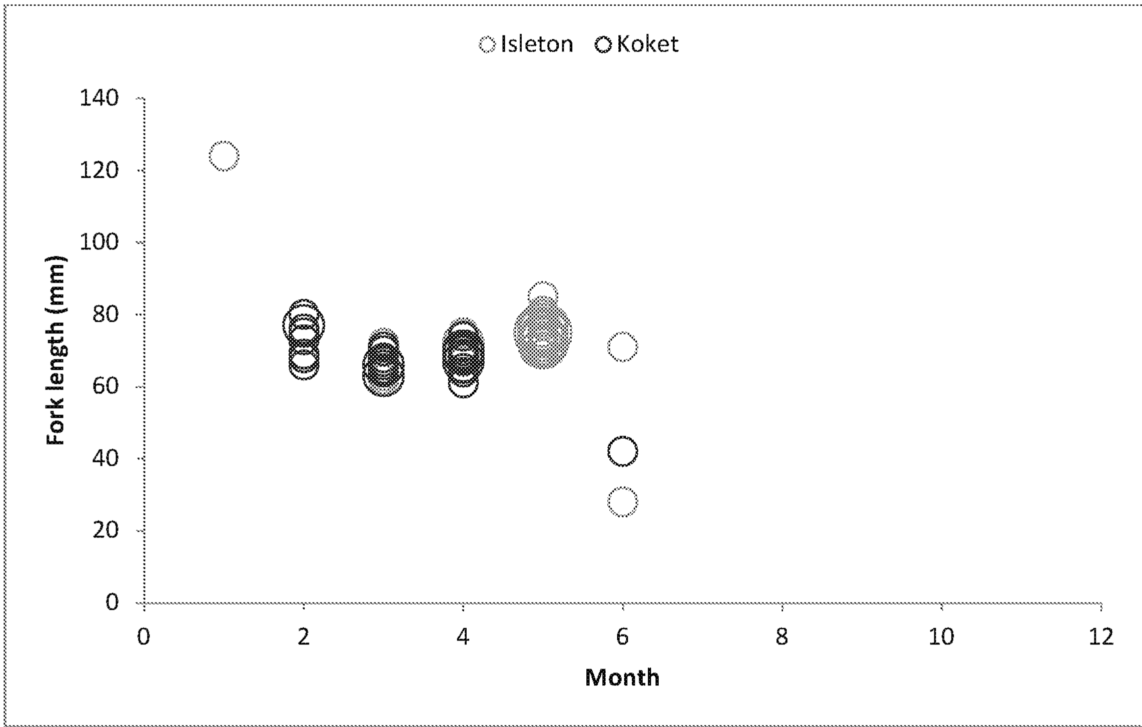

Figure 9.2.1.2-4. Scatterplots of delta smelt size by month for the locations listed in the captions. Delta smelt larger than 50 mm in length are adults. The smallest data points reflect one fish collected at the plotted length, the larger the data point, the more fish of that length were collected. Data source: DJFMP beach seine survey, 1994-2014. Waterways to the east of the Sacramento River in the vicinity of Locke and Walnut Grove: Snodgrass Slough, Lost Slough, the lower Cosumnes River, and the North and South forks of the Mokelumne River adjacent to Staten Island

The adjacent land use along most of this river reach was converted to agriculture around 1915 (Whipple *et al.* 2012; Figure 9.2.1.2-1). Before reclamation, the region was largely riverine though it was under tidal influence as it is today (Florsheim and Mount 2002). Major changes include deforestation of the natural levees, channelization and disconnection of the river from its flanking floodplains and extensive levee reinforcement with riprap. Presently, agriculture is the dominant adjacent land use; however, there are a few natural habitat areas including stands of riparian forest and parcels of freshwater wetlands that are more frequently separated from the river channels by levees than not (Figure 9.2.1.2-5). Since the 1990s, there has been some restoration of the Cosumnes River floodplain at the edge of the Delta's tidal influence (Swenson *et al.* 2003).

Routine trawl-based monitoring programs by CDFW that sample this part of the Delta like the FMWT and the SKT have seldom collected delta smelt (< 1% of the catch; Murphy and Hamilton 2013). The Service's beach seine monitoring program has occasionally collected delta smelt (57 individuals in 21 years) from the few sampling sites it has in this region (Figure 9.2.1.2-6). All 57 collections were adults; similar to the Sacramento River, the collections occurred during the spawning season with observations as late in the year as June 1 in 1999 (Table 9.2.1.2-2). Delta smelt have occasionally been collected from several other locations within this area and up the Mokelumne River as far as Woodbridge Dam (Merz *et al.* 2011; Figure 9.2.1.1-6). No delta smelt were collected during a three-year study of fishes in the Cosumnes River basin during 1999-2001 (Moyle *et al.* 2003). Furthermore, no delta smelt larvae were collected during larval fish surveys of the Cosumnes floodplain restoration areas (Crain *et al.* 2004). The Service concludes this is a transiently used spawning habitat area for delta smelt.

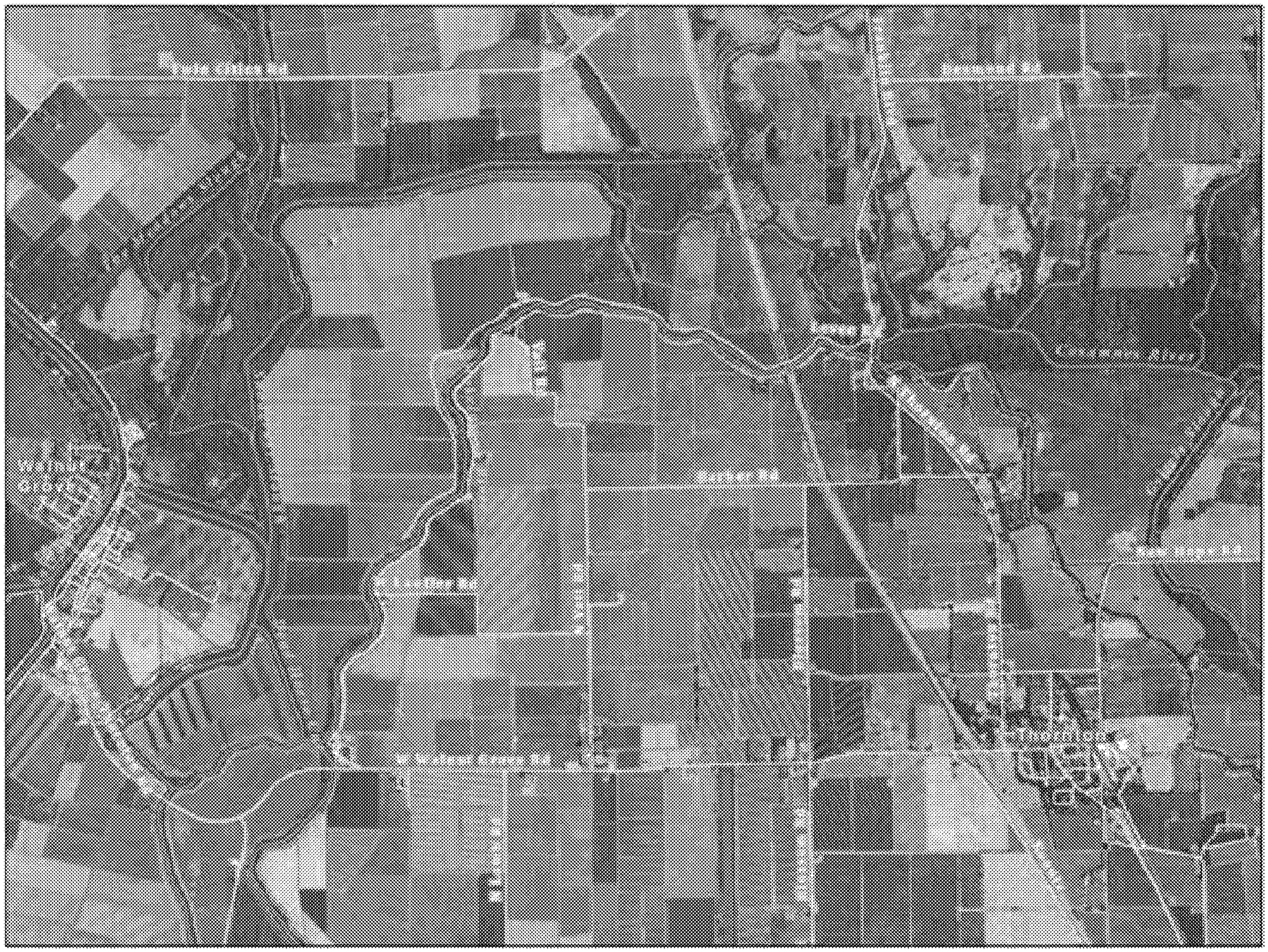

Figure 9.2.1.2-5. National Agriculture Imagery Program (2016) aerial image of the Delta east of Walnut Grove, showing the Mokelumne River system from the Delta Cross Channel to the Cosumnes River floodplain.

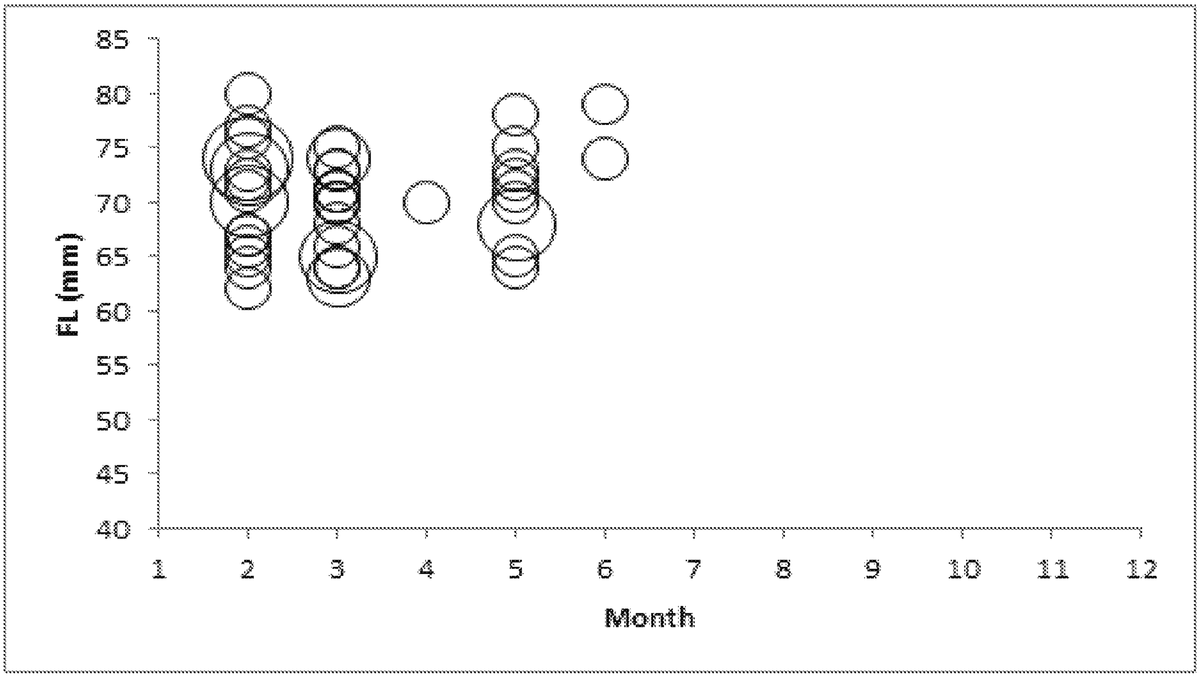

Figure 9.2.1.2-6. Timing and fork lengths of delta smelt collected by Service beach seine surveys at Mokelumne River sites. Delta smelt larger than 50 mm in length are adults, so only adults have been collected in these surveys. The smallest data points reflect one fish collected at the plotted length, the larger the data point, the more fish of that length were collected. Data source: DJFMP beach seine survey, 1994-2014.

Table 9.2.1.2-2. Years in which beach seine surveys conducted by DJFMP have collected delta smelt from Mokelumne River sites.

Location	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Frequency
SF014E (Wimpy's)																						0.29
LP003E (Terminous)																						0.19
MK004W (B&W Marina)																						0.00

Waterways near Prisoners Point

The forks of the Mokelumne River and Georgiana Slough flow into the San Joaquin River along the north and west sides of Bouldin Island. The proposed tunnel alignment crosses under the San Joaquin River at Venice Island just east of Prisoners Point (CWF BA 2016). Historically, this reach of the San Joaquin River system was part of the central Delta's vast 300,000-acre tidal marsh system with a complex, sinuous channel network (Whipple *et al.* 2012). The historical vegetation was dominated by tules. The surrounding landscape was converted to agriculture between 1906 and 1916 (Figure 9.2.1.2-1).

Figure 9.2.1.2-7. National Agriculture Imagery Program (2016) aerial image of the central Delta, including the San Joaquin River region around Prisoners Point.

The major landscape change in this region is the disconnection of the Delta islands from the river channel network and the conversion of the tule marsh plains into agriculture (Whipple *et al.* 2012). The tule peat was burned and otherwise oxidized away over the previous 100 years, leaving the surrounding islands well below sea level (Mount and Twiss 2005). These subsided islands are protected from flooding by riprapped levees. Generally the levees along the north bank of the San Joaquin River are extensively riprapped and as a consequence, largely denuded of vegetation, while the southern bank retains greater amounts of riparian and marsh vegetation.

There are numerous in-channel islands in Potato Slough along the north side of Venice Island and in the San Joaquin River upstream of Prisoners Point (Figure 9.2.1.2-7). The channel edges and remnant wetland complexes in this reach are heavily infested with submerged aquatic vegetation (Durand *et al.* 2016) and slow moving sloughs and smaller channels can have seasonal infestations of water hyacinth as well (Toft *et al.* 2003). These aquatic plants, largely comprised of invasive species, create highly productive microhabitats (Lucas *et al.* 2002; Nobriga *et al.* 2005; Grimaldo *et al.* 2009), but they degrade habitat quality for delta smelt by increasing water transparency (Nobriga *et al.* 2008; Hestir *et al.* 2016) and harboring predatory fishes (Ferrari *et al.* 2014; Conrad *et al.* 2016).

Unlike the proposed construction areas to the north, this region has been monitored more intensively and has been a region of significant fish biological research as well (*e.g.*, Toft *et al.* 2003; Grimaldo *et al.* 2004; Nobriga *et al.* 2005; 2008; Grimaldo *et al.* 2009; 2012). Thus, delta smelt's use of the area is more mechanistically understood here. Each winter, some delta smelt move up the San Joaquin River to spawn. This has been confirmed over the past decade and a half by the CDFW's SKT Survey (http://www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp) and more recently, the Service's Early Warning Surveys (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm). These fish presumably find spawning habitats along sandy beach areas. Grimaldo *et al.* (2004) generally found higher densities of delta smelt larvae in the river channels around Venice Island than the remnant marshes associated with the in-channel islands. The CDFW's 20-mm Survey, which samples channel habitats, has collected larval and small juvenile delta smelt from this region every year of its 21-year history (http://www.dfg.ca.gov/delta/data/20mm/CPUE_map3.asp). However, larvae collected in the San Joaquin River could have either been spawned in the San Joaquin River or have been transported from the Sacramento and Mokelumne systems, which are hydrodynamically connected to the San Joaquin River near Prisoners Point (Kimmerer and Nobriga 2008). The abundance of larval delta smelt in the central Delta usually drops below 20-mm survey detection limits by the end of June and below south Delta diversion fish facilities detection limits about a month later (Figure 9.2.1.2-8). As abundance has decreased, these detection thresholds have shifted earlier in the year because both trawl nets and the fish facilities have minimum densities of fish they can reliably detect, and perhaps because water operations changes initiated under the Service and NMFS BiOps have better enabled larval delta smelt to move seaward during the spring.

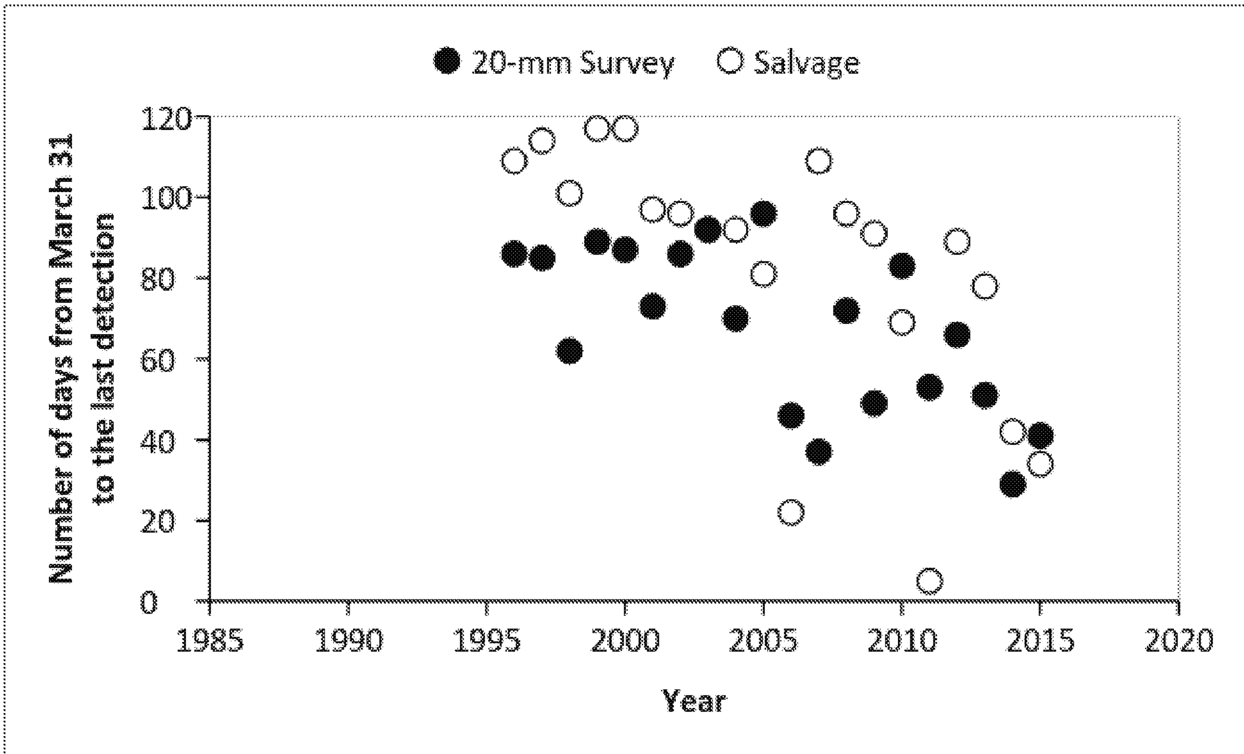

Figure 9.2.1.2-8. Time series of the day of last detection of delta smelt upstream of Jersey Point in the 20-mm Survey and at the CVP or SWP fish facilities. On the y-axis, day 1 is April 1, and day 120 is July 29.

Head of Old River and Other Waterways along the Proposed Tunnel Alignment South of the San Joaquin River Main Stem

The CDFW's striped bass and delta smelt monitoring surveys do not sample in the San Joaquin River upstream of Rough and Ready Island in Stockton (Figure 9.2.1.1-7). Delta smelt have been collected as far up the San Joaquin River as Mossdale (Figure 9.2.1.1-6) and the Service's DJFMP beach seine program has occasionally collected delta smelt in the vicinity of the HOR (Figure 9.2.1.1.7). The Service considers delta smelt that ascend this far up the San Joaquin River to be entrained and as such not functionally contributing to the next generation of fish. Not all entrained delta smelt die in water diversions because many are eaten by predators or otherwise perish in the poor quality habitats of the southern Delta's flooded islands (Franks Tract, Mildred Island) and canals with net reverse flows (Old and Middle river) before they reach the fish facilities. Some of these 'entrained' fish may even have the opportunity to spawn, but PTM shows their larvae would seldom have a hydrodynamic opportunity to escape the south Delta (Kimmerer and Nobriga 2008). In addition, most delta smelt that reach the CVP and SWP intakes are eaten by predators before they can be salvaged (Castillo *et al.* 2012). Delta smelt are seldom collected anywhere in the southern Delta beyond June due to entrainment, increasing water temperature (Kimmerer 2008; Service 2008), and increasing sensitivity to high transparency water as they metamorphose into juveniles (Nobriga *et al.* 2008).

9.2.1.3 Status of the Critical Habitat

Legal Status

The Service designated critical habitat for the delta smelt on December 19, 1994 (Service 1994). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (Service 1994). The entire designated critical habitat for delta smelt is encompassed by the action area for the PA, and the action area encompasses almost the entire range of the delta smelt. Therefore, we combined the *Status of Critical Habitat* and the *Environmental Baseline/Status of Critical Habitat in the Action Area* into one section.

Conservation Role of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful completion of the life cycle, including spawning, larval and juvenile transport, rearing, and adult migration back to spawning sites. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Bay-Delta estuary must provide suitable habitat all year, every year. The primary constituent elements essential to the conservation of the delta smelt are physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration (Service 1994). The Service recommended in its designation of critical habitat for the delta smelt that salinity in Suisun Bay should vary according to WY type. For the months of February through June, this element was codified by the State Water Resources Control Board's "X2 standard" described in D-1641 and the Board's current WQCP.

Description of the Primary Constituent Elements

The original descriptions of the primary constituent elements are compared and contrasted with current scientific understanding in Table 9.2.1.3-1.

Table 9.2.1.3-1. Comparison of delta smelt primary constituent elements of critical habitat between the 1994 publication of the rule and the present.

Primary Constituent Element	1994 critical habitat rule	2016 state of scientific understanding
Spawning Habitat	Shallow fresh or slightly brackish edgewaters.	No change.
	Backwater sloughs.	Possible, never confirmed. Most likely spawning sites have sandy substrates and need not occur in sloughs. Backwater sloughs in particular tend to have silty substrates that would suffocate eggs.
	Low concentrations of pollutants.	No change.
	Submerged tree roots, branches, emergent vegetation (tules).	Not likely. Unpublished observations of spawning by captive delta smelt suggest spawning on substrates oriented horizontally and a preference for gravel or sand that is more consistent with observations of other osmerid fishes.
	Key spawning locations: Sacramento River "in the Delta", Barker Slough, Lindsey Slough, Cache Slough, Prospect Slough, Georgiana Slough, Beaver Slough, Hog Slough, Sycamore Slough, Suisun Marsh.	All of the locations listed in 1994 may be suitable for spawning, but based on better monitoring from the Spring Kodiak Trawl Survey, most adult fish have since been observed to aggregate around Grizzly Island, Sherman Island, and in the Cache Slough complex including the subsequently flooded Liberty Island.
	Adults could spawn from December-July.	Adults are virtually never fully ripe and ready to spawn before February and most spawning is completed by May (warm years) or June (cool years).

Larval and juvenile transport	Larvae require adequate river flows to transport them from spawning habitats in backwater sloughs to rearing habitats in the open waters of the LSZ.	Not likely. Most delta smelt that survive to the juvenile life stage do eventually inhabit water that is in the 0.5 to 6 ppt range, due to either or both of downstream movement or decreasing outflow. However, delta smelt larvae can feed in the same habitats they were hatched in and juvenile fish can rear in water less than 0.5 ppt salinity.
	Larvae require adequate flow to prevent entrainment.	No change.
	Larval and juvenile transport needs to be protected from physical disturbances like sand and gravel mining, diking, dredging, riprapping.	No change, but seems likely to have more impact on spawning habitat than larval transport.
	2 ppt isohaline (X2) must be west of the Sacramento-San Joaquin River confluence to support sufficient larval and juvenile transport.	No change. X2 is generally west of the confluence during February-June due to State Water Resources Control Board X2 standard; however, the standard does have a drought off-ramp.
	Maturation must not be impaired by pollutant concentrations.	No change.
	Additional flows might be required in the July-August period to protect delta smelt that were present in the south and central Delta from being entrained in export pumps.	July-August outflow augmentations may be helpful, but not to mitigate entrainment. Habitat changes in the central and south Delta have rendered it seasonally unsuitable to delta smelt during the summer; entrainment is seldom observed past June.
Rearing habitat	2 ppt isohaline (X2) should remain between Carquinez Strait in the west, Three-Mile Slough on the Sacramento River and Big Break on the San Joaquin River in the east. This was determined to be a range for 2 ppt salinity (including its tidal time scale excursion into the Delta).	No change. X2 generally in this area during February-June due to State Water Resources Control Board X2 standard; however the standard does have a drought off-ramp. Most juvenile delta smelt still rear in this area but it is now recognized that a few remain in the Cache Slough complex as well.

Adult migration	Adults require unrestricted access to spawning habitat from December-July.	Adults disperse faster than was recognized in 1994; most of it is finished by the time Spring Kodiak Trawls start in January, though local movements and possibly rapid longer distance dispersal occurs throughout the spawning season, which as mentioned above is usually February-June or a subset of those months.
	Unrestricted access results from adequate flow, suitable water quality, and protection from physical disturbance.	No change.

Primary Constituent Element 1: "Physical habitat" is defined as the structural components of habitat (Service 1994). The ancestral Delta was a large tidal marsh-floodplain habitat totaling approximately 300,000 acres. During the late 1800s and early 1900s, most of the wetlands were diked and reclaimed for agriculture or other human use (Figure 9.2.1.2-1). The physical habitat modifications of the Delta and Suisun Bay were mostly due to land reclamation and urbanization. Water conveyance projects and river channelization have had some influence on the regional physical habitat by armoring levees with riprap, building conveyance channels like the Delta Cross Channel, storage reservoirs like CCF, and by building and operating temporary barriers in the south Delta and permanent gates and water distribution systems in Suisun Marsh.

During the 1930s to 1960`s, the shipping channels were dredged deeper (~12 m) to accommodate shipping traffic from the Pacific Ocean and San Francisco Bay to ports in Sacramento and Stockton. These changes left Suisun Bay and the Sacramento-San Joaquin River confluence region as the largest and most depth-varying places in the typical range of the low-salinity zone. This region remained a highly productive nursery for many decades (Stevens and Miller 1983; Moyle *et al.* 1992; Jassby *et al.* 1995). However, the deeper landscape created to support shipping and flood control requires more freshwater outflow to maintain the low-salinity zone in the large Suisun Bay/river confluence region than was once required. The shipping itself has historically provided a source of non-native organisms, that along with depleted flows and deep channelization, have contributed to the changing ecology of the upper estuary (Winder and Jassby 2011; Kratina *et al.* 2014).

Although the delta smelt is a generally pelagic or open-water fish, depth variation of open-water habitats is an important habitat attribute (Moyle *et al.* 1992; Hobbs *et al.* 2006). In the wild, delta smelt are most frequently collected in water that is somewhat shallow (4-15 ft deep) where turbidity is often elevated and tidal currents exist but are not excessive (Moyle *et al.* 1992; Bever *et al.* 2016). In Suisun Bay, the deep shipping channels are poor quality habitat because tidal velocity is very high (Bever *et al.* 2016), but in the north Delta where tidal velocity is slower, the Sacramento Deepwater Shipping Channel is used to a greater extent, particularly for spawning and by larval fish (CDFW unpublished data). Adult delta smelt also use edge habitats as tidal current refuges and corridors to spawning habitats (Bennett and Burau 2015).

Primary Constituent Element 2: "Water" is defined as water of suitable quality to support various delta smelt life stages that allow for survival and reproduction (Service 1994). Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt and are discussed in detail below. Contaminant exposure can degrade this primary constituent element even when the basic habitat components of water quality are otherwise suitable (Hammock *et al.* 2015).

Turbidity: Delta smelt require turbidity. Even in captivity, clear water is a source of physiological stress (Lindberg *et al.* 2013; Hasenbein *et al.* 2016). The small plankton that delta smelt larvae eat are nearly invisible in clear water. The sediment (or algal) particles that make turbid water turbid, provide a dark background that helps delta smelt larvae see their translucent prey (Baskerville-Bridges *et al.* 2004). Older delta smelt are less reliant on turbidity to see their prey, but older fish still feed more effectively in water of moderate turbidity (Hasenbein *et al.*

2013; 2016) and probably need turbid water to help disguise themselves from predators (Ferrari *et al.* 2014). The turbidity of the Delta and Suisun Bay has been declining for a long time due to dams and riprapped levees, both of which cut off sources of sediment from rivers flowing into the estuary (Arthur *et al.* 1996; Wright and Schoellhamer 2004), and due to the spread of Brazilian waterweed (Hestir *et al.* 2016) which filters the water, increasing clarity. Water exports from the south Delta may also have contributed to the trend toward clearer water by removing resuspended sediment in the exported water (Arthur *et al.* 1996). The primary turbid areas that remain in the upper estuary are the semi-shallow embayments in northern Suisun Bay (Bever *et al.* 2016) and the lower Yolo Bypass region that includes Liberty Island and the upper reach of the Sacramento Deepwater Shipping Channel (Morgan-King and Schoellhamer 2013). Both tidal and river flows, as well as wind speed, affect turbidity in these locations. Many of the estuary's deeper channels tend to have somewhat lower turbidity because water velocity and wind cannot resuspend sediment that sinks into deep water (Ruhl and Schoellhamer 2004).

Water temperature: Water temperature is the primary driver of the timing and duration of the delta smelt spawning season (Bennett 2005). Water temperature also affects delta smelt's growth rate which in turn can affect their readiness to spawn (Rose *et al.* 2013a). Water temperature is not strongly affected by variation in Delta outflow; the primary driver of water temperature variation in the delta smelt critical habitat is air temperature (Wagner *et al.* 2011). Very high flows can transiently cool the upper estuary (*e.g.*, flows in the upper 10th percentile, Kimmerer 2004), but the system rapidly re-equilibrates once air temperatures begin to warm.

Older laboratory based research suggested an upper water temperature limit for delta smelt of about 25°C, or 77°F (Swanson *et al.* 2000). Newer laboratory research suggests delta smelt temperature tolerance decreases as the fish age, but is a little higher than previously reported, up to 28°C or 82°F in the juvenile life stage (Komoroske *et al.* 2014). It should be kept in mind that these are upper *acute* water temperature limits, meaning temperatures in this range will kill, on the average, one of every two fish.

In the laboratory and the wild, delta smelt appear to have a physiological optimum temperature near 20°C or 68°F (Nobriga *et al.* 2008; Rose *et al.* 2013a; Jeffries *et al.* 2016); most of the upper estuary exceeds this water temperature from June through September (Wagner *et al.* 2011). Thus, many parts of the estuary are energetically costly and stress delta smelt. Generally speaking, spring and summer water temperatures are cooler to the west and warmer to the east due to the differences in overlying air temperatures between the Bay Area and the warmer Central Valley (Kimmerer 2004). In addition, there is a strong water temperature gradient across the Delta with cooler water in the north and warmer water in the south. The higher flows from the Sacramento River probably explain this north-south gradient. Note that water temperatures in the north Delta near Liberty Island and the lower Yolo Bypass are also typically warmer than they are along the Sacramento River (Sommer *et al.* 2001; Nobriga *et al.* 2005).

Food: Food and water temperature are strongly interacting components of delta smelt health and habitat because the warmer the water, the more food delta smelt require (Rose *et al.* 2013a). If the water gets too warm, then no amount of food is sufficient. The more food delta smelt eat (or must try to eat) the more they will be exposed to predators and contaminants. Water exports can limit the flux of phytoplankton production from the Delta into Suisun Bay (Jassby and Cloern 2000), but the effect of water exports on phytoplankton production appears to be lower than grazing by clams (Jassby *et al.* 2002) and ammonium inhibition of phytoplankton growth from Sacramento's urban wastewater inputs (Dugdale *et al.* 2012).

Historically, prey production occurred when the low-salinity zone was positioned over the shoals of Suisun Bay during late spring through the summer, but this function has been depleted due to grazing by overbite clams (Kimmerer and Thompson 2014), high ammonium concentrations in critical habitat (Dugdale *et al.* 2012; 2016), and water diversions (Jassby and Cloern 2000). Recent research suggests delta smelt occupying Suisun Bay may experience poor nutritional health (Hammock *et al.* 2015). Delta smelt occupying the Cache Slough region in the north Delta are in better nutritional health, but have shown evidence of relatively high contaminant impacts. The southern Delta is among the more productive areas remaining in the upper estuary (Nobriga *et al.* 2005), but delta smelt cannot remain in this habitat during the warmer months of the year (Nobriga *et al.* 2008) and may face a high risk of entrainment when they occupy it during cooler months (Kimmerer 2008; Grimaldo *et al.* 2009). Extensive blooms of the toxin-producing cyanobacteria *Microcystis* in the central and southern Delta became abundant around 1999 and depending on flow, and temperature, blooms can extend westward into the low-salinity zone where delta smelt are rearing (Brooks *et al.* 2011). However, in general delta smelt that occupy Suisun Marsh fare better both in terms of nutrition and in experiencing a lower level of contaminant impacts (Hammock *et al.* 2015).

<u>Primary Constituent Element 3</u>: "River flow" was originally defined as transport flow to facilitate spawning migrations and transport offspring to low-salinity zone rearing habitats (Service 1994). River flow includes both "inflow to" and "outflow from" the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflows, outflows, and Old and Middle river flows influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at the Banks and Jones facilities (Grimaldo *et al.* 2009).

The spawning microhabitats of delta smelt are not known, but whatever they are, it is likely there is more available suitable spawning habitat when Delta outflow is high during spawning than when it is low because more of the estuary is covered in fresh- and low-salinity water when outflow is high (Jassby *et al.* 1995). Most spawning occurs between February and May. Delta outflow during February through May is mainly driven by the climatic effect on the amount and form of precipitation in the watershed, the storage and diversion of water upstream of the Delta, and CVP and SWP water operations in the Delta (Jassby *et al.* 1995; Kimmerer 2002a). Thus far, the 21st century has tended to be pretty dry (Figure 9.2.1.1-8) and that could have resulted in some chronic reduction in spawning habitat availability or suitability.

<u>Primary Constituent Element 4</u>: "Salinity" helps define nursery habitat (Service 1994). Older laboratory research suggested that delta smelt have an upper acute salinity tolerance of about 20 ppt (Swanson *et al.* 2000) which is about 60% of seawater's salt concentration of 32-33 ppt. Newer laboratory-based research suggests that some individuals can acclimate to seawater, but that comes at a high energetic cost that is lethal to about one in four individuals (Komoroske *et al.* 2014; 2016). In the wild, delta smelt are nearly always collected at very low salinities, which

recent laboratory research has confirmed is nearer to the physiological optimum (Komoroske *et al.* 2016). Few individuals are collected at salinities higher than 6 ppt (about 20% of seawater salt concentration) and very few are collected at salinities higher than 10 ppt (about 30% of seawater salt concentration) (Bennett 2005). This well documented association with fresh to low salinity water is a reason for the scientific emphasis on X2 as a delta smelt habitat indicator (Dege and Brown 2004; Feyrer *et al.* 2011). Recent research combining long-term monitoring data with three-dimensional hydrodynamic modeling shows that the spatial overlap of several of the key habitat attributes described above increases as Delta outflow increases (Bever *et al.* 2016). This means that higher outflow, which lowers the salinity of Suisun Bay and Suisun Marsh, increases the suitability of habitat in the estuary by increasing the overlap of some, but not necessarily all, needed elements. Lower outflows provide less overlap and in fewer places.

Summary of Status of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful completion of the life cycle, including spawning, larval and juvenile transport, rearing, and adult migration back to spawning sites. Since the implementation of the RPA in the Service's 2008 BiOp, there has been a lower likelihood of water operations that are highly detrimental to the spawning migration of adult delta smelt, the spawners themselves, or larval transport. Further, recent research suggests that the movement of adult delta smelt to nominal spawning locations is quite similar among years (Polansky *et al.* in press).

There are very few locations that consistently provide all the needed habitat attributes for larval and juvenile rearing at the same times and in the same places (Table 9.2.1.3-2; IEP 2015). Larval and juvenile rearing remains most impacted by ecological changes in the estuary since the delta smelt's listing under the Act. As described above, those changes have stemmed from changes in outflow, species invasions and associated changes in how the upper estuary food web functions, declining prey availability, high water temperatures, declining water turbidity, summertime blooms of *Microcystis aeruginosa*, proliferation of submerged aquatic plants, and localized contaminant accumulation by delta smelt.

Table 9.2.1.3-2. Summary of habitat attribute conditions for delta smelt in six regions of the estuary that are permanently or seasonally occupied in most years.

	Landscape	Turbidity	Salinity	Temperature	Food
Montezuma Slough	Appropriate	Appropriate	Appropriate *when outflow is sufficient*	Usually appropriate	Appropriate
Suisun Bay	Appropriate except in shipping channel	Appropriate, but declining	Appropriate *when outflow is sufficient*	Usually appropriate	Depleted
West Delta	Limited area 4 to 15 ft deep	marginal, declining	Appropriate	Can be too high during summer	Depleted
North Delta (Cache Slough region)	Appropriate	Appropriate	Appropriate	Can be too high during summer	Appropriate, but associated with elevated contaminant impacts
Sacramento River near proposed NDD	Limited area 4 to 15 ft deep; swift currents	Marginal except during high flows, declining	Appropriate	Usually appropriate	Likely low due to swift currents and wastewater inputs
South Delta	Appropriate except too much coverage by submerged plants	Too low	Appropriate	Too high in the summer	Appropriate

9.2.1.4 Existing Conditions and Previous Consultations in the Action Area

9.2.1.4.1 Consultation of the Coordinated Long-Term Operations of the CVP and SWP

Background

The CVP and SWP are California's two largest water storage and delivery systems. The CVP and SWP include major reservoirs north and south of the Delta; both projects transport water via natural watercourses and canal systems to areas throughout much of California. For both the CVP and the SWP, the primary north to south transfer point is the Delta where water is exported to the south from the C.W. "Bill" Jones and Harvey O. Banks pumping plants into the Delta-Mendota Canal and the California Aqueduct, respectively. Additionally, CVP water is also exported from the Delta via the Contra Costa Water District facilities to the Bay Area and SWP water is also exported from the Delta via the Barker Slough Pumping Plant.

The California State Water Resources Control Board (SWRCB) permits the CVP and SWP to store, release, and divert water and to divert natural runoff. The CVP and SWP operate pursuant to water rights permits and licenses issued by the SWRCB. As conditions of their water rights permits and licenses, the SWRCB requires the CVP and SWP to meet specific water quality, quantity, and operational criteria within the Delta. Reclamation and the DWR closely coordinate the CVP and SWP operations to meet these obligations.

2008 Service BiOp on the Coordinated Operations of the CVP and SWP

In 2008, the Service issued a BiOp that concluded that the continued long-term operation of the CVP and SWP was likely to jeopardize the continued existence of delta smelt and destroy or adversely modify its critical habitat. The Service included a RPA to avoid jeopardy and adverse modification. Reclamation provisionally accepted the RPA and began implementing the BiOp and the RPA in December 2008. This BiOp is currently in effect.

Key elements of the Service's RPA in the 2008 BiOp are:

RPA Component 1: The objective of Component 1 (comprised of Actions 1 and 2) is to reduce entrainment of pre-spawning adults by controlling OMR flows during periods of elevated entrainment risk. Action 1 is designed to protect migrating delta smelt. Action 2 is designed to protect adult delta smelt that are residing in the Delta prior to spawning. Overall, RPA Component 1 increases the suitability of spawning habitat for delta smelt by decreasing the amount of Delta habitat affected by the CVP and SWP export pumping plants' operations prior to, and during, the critical spawning period;

RPA Component 2: The objective of Component 2 is to limit entrainment of larval and juvenile delta smelt by reducing net negative flow conditions in the central and south Delta, so that larval and juvenile delta smelt can successfully rear in the Delta and move downstream when appropriate;

RPA Component 3: The objective of Component 3 is to improve fall habitat conditions for delta smelt by increasing Delta outflow during fall of Wet and Above-normal years to re-establish variability in habitat conditions during this time of year;

RPA Component 4: The objective of Component 4 is to restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh to increase prey production for delta smelt; and

RPA Component 5: Component 5 provides for monitoring and reporting. Reclamation and DWR shall ensure that information is gathered and reported to ensure: (1) proper implementation of the restoration actions, (2) that the physical results of the restoration actions are achieved, and (3) that information is gathered to evaluate the effectiveness of these actions on the targeted life stages of delta smelt so that the actions can be refined, if needed.

For more information, the 2008 Service BiOp can be found at:
https://www.fws.gov/sfbaydelta/documents/SWP-CVP_OPs_BO_12-15_final_signed.pdf

2009 NMFS BiOp on the Coordinated Operations of the CVP and SWP

NMFS issued its current coordinated operations of the CVP and SWP BiOp on June 4, 2009. The NMFS BiOp covers: Central California Coast steelhead and its critical habitat; Sacramento River winter-run Chinook salmon; Central Valley spring-run Chinook salmon; Central Valley steelhead; Southern Distinct Population Segment (DPS) of Northern American green sturgeon; and Southern resident DPS of killer whales. NMFS determined that the action was likely to jeopardize these species and destroy or adversely modify their critical habitat, except the Central California Coast steelhead, and included an RPA.

Key elements of the NMFS RPA in the 2009 BiOp are:

- A new temperature management program for Shasta Reservoir and the Sacramento River below Keswick Dam;
- Long-term passage prescriptions at Shasta Dam to allow re-introduction of listed salmonids;
- Flow and temperature criteria in Clear Creek below Whiskeytown Dam;
- A new screened pumping plant in Red Bluff to replace the Red Bluff Diversion Dam (completed in 2012);
- Improved juvenile salmonid fish rearing habitat in the lower Sacramento River and Delta;
- Delta Cross Channel gate closure beyond the mandates of D-1641;
- An OMR flow limit of -5000 cfs from January 1 through June 30 with salvage-based triggers that can limit OMR flow to less negative values;
- A limit on the ratio of exports to San Joaquin River inflow during April and May;
- Required studies of acoustic tagged steelhead in the San Joaquin Basin to evaluate the effectiveness of the RPA and refinements as necessary;